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Zonation by ammonites and foraminifers of the Vraconnian-Turonian interval: A comparison of the Boreal and Tethyan domains (NW Europe / Central Tunisia)

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Abstract: Since the end of the 19th century the interval comprising the uppermost Upper Albian, the Cenomanian, the Turonian and the basal Coniacian has been subdivided, first into ammonite zones, then, beginning in the middle of the 20th century, into zones of planktonic foraminifera. These two groups, one macrofossil, the other microfossil, are particularly effective for bio-chronostratigraphy thanks to their rapid rates of evolution. But differences in the faunal makeup between the Boreal domain (northwestern Europe) and the Tethyan domain (Mediterranean) have for a long time hindered precise correlation of the two domains. Today, in a time interval covering about 16 million years, there are 29 ammonite zones in the Tethyan domain versus 24 in the Boreal one, of which 16 are common to both domains. For the planktonic foraminifera the Tethyan domain has 11 zones, the Boreal domain 10, with 7 in common.

Key Words: Cretaceous; Albian; Vraconnian; Cenomanian; Turonian; ammonites; foraminifers; zones; zonation; Tethys.

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Résumé : *Zones d'ammonites et de foraminifères du Vraconnien au Turonien : Une comparaison entre les domaines boréal et téthysien (NW Europe / Tunisie centrale).*- Depuis la fin du 19^{ème} siècle, l'intervalle comprenant l'Albien supérieur élevé, le Cénomaniens, le Turonien et le Coniacien basal a été subdivisé d'abord en zones d'ammonites puis, à partir du milieu du 20^{ème} siècle, en zones de foraminifères planctoniques, deux groupes de macro- et de microfossiles particulièrement efficaces en bio-chronostratigraphie grâce à leur taux d'évolution rapide. Toutefois, des différences de compositions fauniques entre le domaine boréal (Europe du Nord-Ouest) et le domaine téthysien (Méditerranée) ont longtemps empêché des corrélations précises entre ces deux domaines. Aujourd'hui, dans un intervalle de temps couvrant environ 16 millions d'années, on dénombre 29 zones d'ammonites en domaine téthysien contre 24 en domaine boréal parmi lesquelles 16 sont communes aux deux domaines. Pour les foraminifères planctoniques, on compte 11 zones en domaine téthysien et 10 en domaine boréal, dont 7 communes.

Mots-Clefs : Crétacé ; Albien ; Vraconnien ; Cénomaniens ; Turonien ; ammonites ; foraminifères ; zones ; zonation ; Téthys.

Introduction

The biostratigraphic studies that we have undertaken for several decades in the Boreal and Tethyan realms have yielded a great amount of data, so here we synthesize the information about the ammonite and foraminiferal zones recognized in the "middle" Cretaceous of the two domains (AMÉDRO, 1992, 2002, 2008; AMÉDRO & ROBASZYNSKI, 2001 a-b; AMÉDRO *et alii*, 2005; ROBASZYNSKI *et alii*, 1990, 1994). The results of a comparison of the several zones are shown on a table (Table) which provides a clear understanding of the choices made in its construction. Such a comparison of zones should not be taken as a purely academic exercise, but rather as an

attempt to compare biostratigraphic intervals that should facilitate a more precise synchronization in the two domains of the events, lithologic, biologic, geochemical, eustatic that took place in the medial portion of Cretaceous times.

I – Choices made in constructing the table (Table)

The reference zonation was chosen to be that of the ammonites of Tunisia, in spite of the fact that for the middle Cretaceous two of the three stage boundaries are defined with a planktonic foraminifer and an inoceramid species. However, it appears that insofar as ma-

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crofossil time-markers are concerned, ammonites are both the most abundant paleontologic material and the most determinative in indicating platform deposits, be they proximal or distal (AMÉDRO in ROBASZYNSKI *et alii*, 1990, 1994).

The number of ammonite zones in Tunisia is greater than those of the Boreal domain, for at least two reasons: (i) deposition of sediments was more continuous -thus more nearly complete- for it was taking place in a basin more subsident than those of the intracratonic basins of northwestern Europe, (ii) there, starting in Albian times, connections with North American and African provinces were established and immigrants from these provinces are associated with or replace Tethyan faunas.

In the table (Table), the zones recognized or created in Tunisia are in successive boxes of the same size, but this does not mean that they are all of the same time length. This form was chosen because, although the duration of several has begun to become known (CARON *et alii*, 1999), the length of many is far from being established. Probably the work on dating volcanic ash in company with detailed cyclostratigraphic studies will add a lot to the measurement of the length of zones.

The planktonic foraminiferal zones are placed in respect to the Tunisian ammonite zones in accordance with information obtained from records of their vertical ranges made in the same sections as those that furnished the ammonites (ROBASZYNSKI *et alii*, 1990, 1994).

II - Characteristics and comparison of the two ammonite zonation of the middle Cretaceous

1 - NW Europe: Anglo-Paris Basin, Westphalia and southeastern France (Rhône valley and the Vocontian domain)

The ammonite zonation currently in use for the middle Cretaceous of NW Europe, an area that includes the historical stratotypes of the Albian, Cenomanian and Turonian stages, is one of the most precise known. Its examination calls for several remarks: (i) most of the markers of the zones have a broad geographic distribution; (ii) where it is possible, the species chosen are in the same phyletic lineage, for example in the Upper Albian-Vraconnian the succession is *Mortonicer* with two tubercles per rib (*M. pricei*), then three (*M. inflatum*, *M. fallax*) and

finally four tubercles per rib (*M. perinflatum*); (iii) except in the Vocontian domain (Mont Risou, KENNEDY *et alii*, 1996) an important gap in sedimentation marks a hiatus in the succession of ammonite faunas; (iv) in the Middle Turonian, while the chalk facies of the northern Anglo-Paris Basin and of Westphalia (KAPLAN *et alii*, 1996) contain a typically Boreal fauna with *Collignonicer*, the "tuffeaux" (porous limestones) of the southern border of the basin (Saumur, Bourré, Poncé) and the sandstones of the Rhône valley (Uchaux) contain mixed faunas, rich in *Kamerunoceras*, then in *Romanicer*. These intermediate areas form precious links between the Boreal and Tethyan domains.

2 - Central Tunisia

The ammonite zonation now used for the middle part of the Cretaceous succession has progressed in relation to the previous divisions recognized by PERVINQUIÈRE (1903, 1907) and DUBOURDIEU (1956). Its detail is often better to that obtained in the intra-cratonic basins of NW Europe, because of the continuous and thicker deposition, and an extraordinarily rich ammonite fauna at almost all the levels.

3 - Comparison

There are numerous kinships between the ammonite zones of NW Europe (Boreal and north Tethyan domains) and those of Tunisia (southern Tethyan domain). Nevertheless, several intervals have no direct correlation. These coincide in particular with the limits of stages (eustatic events, lowering of sea level). But on the other hand, at these levels there is the remarkable occurrence in Tunisia of the episodic occurrence of ammonites with North American affinities, successively: (i) at the limit between Albian (Vraconnian) and Cenomanian: *Graysonites* (AMÉDRO in ROBASZYNSKI *et alii*, 2007); (ii) in the Middle Cenomanian: *Paraconlinoceras barcusi*, *Acanthoceras amphibolum*; (iii) at the Cenomanian-Turonian boundary: *Pseudaspidoceras pseudodosoides*, *Watinoceras* sp., *Pseudaspidoceras flexuosum*; (iv) in the Upper Turonian: *Prionocyclus novimexicanus*, *P. germari*. These successive phases of migration are probably linked to eustatic events (Transgressive Intervals of 3rd order eustatic cycles). All of this demonstrates the existence of numerous relationships between the Boreal and Tethyan domains, not only between northwestern Europe and Tunisia but also, in a more ephemeral way, between the North-American continent and Tunisia.

Ma ODIN 1994	Ma OGG <i>et al.</i> 2004	stages	Boreal domain N.W. EUROPE			Tethyan Domain CENTRAL TUNISIA			
			benthic foraminifers	planktonic foraminifers	ammonites	ammonites	planktonic foraminifers		
88 ± 2	89,3 ± 1.0	CONIAC. ↑ <i>C. d. erectus</i>	<i>Reussella</i>		<i>Forresteria petrocariensis</i>		<i>Barroisiceras cf. tunetanum</i>		
			<i>kelleri</i>		<i>Prionocyclus germari</i>		<i>Prionocyclus germari</i> *	<i>Dicarinella</i>	
			<i>Globorotalites michelinianus</i>	<i>Marginotruncana coronata</i>	<i>Subprionocyclus neptuni</i>		<i>Prionocyclus novimexicanus</i> *	<i>concovata</i>	
			<i>Bdelloidina cribosa</i>		<i>Romaniceras deverianum</i>		<i>Prionocyclus sp. & Subpriono. neptuni</i>		
			<i>Globorotalites hangensis</i>	<i>Marginot. sigali</i>	<i>Romaniceras deverianum</i>		<i>Romaniceras deverianum</i>	<i>Marginotruncana</i>	
					<i>Collign. woolgari</i>		<i>Collipoceras interval</i>	<i>schneegansi</i>	
					<i>Roman. ornatis.</i>		<i>Romaniceras kallesi</i>	<i>Marg. sigali</i>	
					<i>Roman. kallesi</i>		<i>Kamerunoceras turoniense</i>		
					<i>Mammites nodosoides</i>		<i>Mammites nodosoides</i>	<i>Helvetoglobotruncana helvetica</i>	
					<i>Helvetoglobotruncana helvetica</i>		<i>Thomasites rollandi</i>		
92 ± 2	93,5 ± 0.8	↑ <i>W. devonense</i>	<i>Lingulogavelinella globosa</i>	<i>Whitein. praehelv.</i>	<i>Fagesia catinus</i>		<i>Pseudaspidoceras flexuosum</i> *	<i>Whitein. praehelv.</i>	
				<i>Whiteinella archaeocretacea</i>	<i>Watinoceras devonense</i>		<i>Watinoceras sp.</i>	<i>Whitein. archaeocretacea</i>	
					<i>Neocardioceras juddii</i>		<i>Pseudaspidoceras pseudonodosoides</i> *		
					<i>Metioceras geslinianum</i>		<i>Metioceras geslinianum</i>		
					<i>Calyoceras guerangeri</i>		<i>Eucalyoceras pentagonum</i>	<i>Rotalipora</i>	
					<i>Flourensina maniae</i>	<i>Rotalipora cushmani</i>	<i>Acanthoceras jukesbrowni</i>	<i>Acanthoceras amphibolum</i> *	<i>cushmani</i>
							<i>Acanthoceras rhotomagense</i>	<i>Paraconlinoceras aff. barcusi</i> *	
					<i>Pseudotextulariella cretosa + Hagenowina advena</i>	<i>Thalmaninella reichelli</i>	<i>Cunningtoniceras ineme</i>	<i>Acanthoceras cf. rhotomagense</i>	<i>Thalm. reichelli</i>
							<i>Mantelliceras dixonii</i>	<i>Cunningtoniceras ineme</i>	<i>Thalmaninella</i>
						<i>Thalmaninella globotruncanoides</i>	<i>Mantelliceras mantelli</i>	<i>Mantelliceras cf. mantelli</i>	<i>globotruncanoides</i>
96 ± 2	99,6 ± 0.9	↑ <i>R. globotr.</i>	<i>Arenobulimina sabulosa + Orithostella jarzevae</i>	<i>Thalmaninella appenninica</i>	<i>non reconnu</i>		<i>Graysonites cobbani</i> *	<i>(= brotzeni)</i>	
					<i>Arrhaphoceras briacensis</i>		<i>Graysonites azregensis</i> *		
					<i>Mortoniceras perinflatum</i>		<i>Stoliczkaia africana</i>	<i>Thalmaninella appenninica</i>	
					<i>Mortoniceras rostratum</i>		<i>Mortoniceras perinflatum</i>		
					<i>Mortoniceras fallax</i>		<i>Mortoniceras rostratum</i>		
							<i>Mortoniceras fallax</i>		
					<i>Arenobulimina chapmani</i>	<i>Ticinella primula</i>	<i>Mortoniceras inflatum</i>	<i>Mortoniceras inflatum</i>	<i>Pseudothalmann. ticinensis</i>
							<i>Mortoniceras pricei</i>	<i>Mortoniceras pricei</i>	



no direct correlations

* species with North American affinities

Table: An attempt to correlate the zonation of ammonites and foraminifers in northwestern Europe (Boreal domain) with that of central Tunisia (Tethyan domain). The up- and down- pointing arrows indicate respectively the first and last appearances of the taxa concerned.

III - Foraminiferal zonations

1 - Central Tunisia

The sections were made in areas where sedi-

mentation was intermediate between platform and basin. The Kalaat Senan region is in the outer platform domain, in a distal relationship to the coast, with deposits essentially argillaceous and marly in the Albian-Lower

Cenomanian and then with the development of carbonate beds intercalated in the marls that start in the Cenomanian and continue up through the Coniacian and even higher. The marly facies delivers planktonic foraminifers with Tethyan characteristics: large (0.3 to 0.7mm, sometimes up to 1mm), the non-globular morphotypes have well-marked and often thick keels, with numerous transitional forms between species. Moreover, benthic forms with agglutinated or calcareous tests are generally associated with planktonic forms but have less significance for chronostratigraphy.

In Tunisia, the zones recognized between the Vraconnian and the Coniacian are more or less the "standard zonation" that since the middle of the 20th century has been established and improved (BOLLI, 1966; SIGAL, 1987; ROBASZYNSKI & CARON, 1979; details in ROBASZYNSKI & CARON, 1995, and in GONZÁLEZ-DONOSO *et alii*, 2007), with the succession: *Thalmaninella appenninica*, *T. globotruncanoides* (= *brotzeni*), *T. reicheli*, *Rotalipora cushmani*, *Whiteinella archaeocretacea*, *W. praehelvetica*, *Helvetoglobotruncana helvetica*, *Marginotruncana schneegansi*, *Dicarinella concavata*.

Remarks

As *Thalmaninella globotruncanoides* has been chosen as the marker of the base of the Cenomanian, it implies that the last *Stoliczkaia* ammonites -among which is the index of the zone, that is *Stoliczkaia (Shumarinaia) africana*- are not confined to the Albian (Vraconnian) but "climb" into the basal Cenomanian. For the two other limits of stages the planktonic foraminifers have no bioevents to serve as true markers. However, they can be used as "proxies": for example as regards the Cenomanian-Turonian boundary the first *Whiteinella praehelvetica* (very rare) with flattened chambers on the spiral side are already noted in the *Pseudaspidoceras pseudonodosoides* Zone of the uppermost Cenomanian, but at the Turonian-Coniacian limit there is no major extinction or appearance of foraminifera.

2 - Northwestern Europe

In the Paris-London Basin of the Boreal domain, the chalk sea was favourable to the development of keeled planktonic foraminifera only during the Cenomanian-Middle Turonian interval, that is in facies during which marl was also deposited. The installation of pure chalk facies starting in the Upper Turonian was no longer favourable (sea too shallow?) so only less informative globular forms are collected. From Upper Albian to Lower Turonian the zones are identical to those of the Tethyan domain, although the keels of the morphotypes are weakly developed.

Remark: there appears to be a slight diachronism of the *Thalmaninella reicheli* Zone (apparently younger in Tunisia, unless the ammonites are responsible?).

In return, the benthic foraminifera are often much more numerous and, starting in the Middle Turonian, it is with them that a biostratigraphic zonation can be made, up to the higher levels of the Santonian (the Boulonnais, ROBASZYNSKI & AMÉDRO, 2001) and up to the Campanian-Maastrichtian (Kent).

Conclusions

- A comparison of the ammonite zones of the Boreal and Tethyan domains shows numerous affinities between the two domains: almost two-thirds are the same.

- In Tunisia, nearly a third of the zones are based on species with North American affinities, so constitute excellent guides for intercontinental correlation.

- Planktonic foraminifera have only a third of the number of zones provided by ammonites. This disadvantage is compensated for by the fact that foraminiferal zones are global and that they can be recognized in the subsurface, in wells for example.

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